

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE Feb. 7, 2000	3. REPORT TYPE AND DATES COVERED 1/1/97 - 12/31/99
4. TITLE AND SUBTITLE "Adaptive Optics Imaging of Solar System Objects"			5. FUNDING NUMBERS NAG5-3731
6. AUTHORS Francois Roddier			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Hawaii Institute for Astronomy			8. PERFORMING ORGANIZATION REPORT NUMBER 6-54592
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration			10. SPONSORING/MONITORING AGENCY REPORT NUMBER NAG503731
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT DISTRIBUTION STATEMENT A Approved for Public Release Distribution Unlimited			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) Adaptive optics observation of Saturn's ring plane crossing, Neptunes atmospheric activity, volcanoes on Io, and Titan. Photometry of Pluto and Charon. Surface mapping of Ceres, Pallas and Vesta. Detection of Neptue's arcs and dark satellites.			
14. SUBJECT TERMS Saturn, Neptune, Io, Titan, Pluto, Charon, Ceres, Pallas, Vesta			15. NUMBER OF PAGES 4 pages
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

University of Hawaii

Final Technical Report

Submitted to the

National Aeronautics and Space Administration

Grant No. NAG5-3731

"Adaptive Optics Imaging of Solar System Objects"

January 1, 1997 to December 31, 1999

Submitted by

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FINAL REPORT

GRANT TITLE: Adaptive Optics Imaging of Solar System Objects

PRINCIPAL INVESTIGATOR: François Roddier (Co-Investigator: Toby Owen)

INSTITUTION: Institute for Astronomy (IfA), University of Hawaii (UH).

Goals:

Most solar system objects have never been observed at wavelengths longer than the R band with an angular resolution better than 1". The Hubble Space Telescope itself has only recently been equipped to observe in the infrared. However, because of its small diameter, the angular resolution is lower than that one can now achieved from the ground with adaptive optics, and time allocated to planetary science is limited. We have successfully used adaptive optics on a 4-m class telescope to obtain 0.1" resolution images of solar system objects in the far red and near infrared (0.7–2.5 μm), at wavelengths which best discriminate their spectral signatures. Our efforts have been put into areas of research for which high angular resolution is essential.

Accomplishments:

- 1) *Adaptive optics observations of Saturn's ring plane crossing in August 95.* For the first time, satellites discovered by the Voyager space probe such as Prometheus and Pandora were observed from the ground and their infrared magnitudes determined, giving clues to their surface composition. Whereas HST observers were able to identify three clumps in the F ring, our observations revealed nine additional clumps, helping to better understand the phenomenon (Roddier *et al.*, Icarus **143**, in press). Two nights after the crossing, evidence was found for a decaying arc of particles scattered along an orbit close to that of Enceladus. A possible explanation is that a large block of ice previously ejected by Enceladus collided with ice fragments trapped on the satellite orbit. The collision produced an expanding cloud of small ice particles which quickly vaporized, an event never observed before (Roddier *et al.*, Icarus **136**, p. 50, 1998). In addition, an eclipse of Epimetheus was photometrically analyzed, giving new constraints on the inclination of Epimetheus' orbit (Roddier *et al.*, ESO/OSA Sonthofen meeting)
- 2) *Adaptive optics monitoring of Neptune's atmospheric activity.* Differences in Neptune's atmospheric opacity have allowed us to isolate high-altitude cloud layers from lower ones. Maximum atmospheric activity is apparently moving from the North hemisphere back to the South hemisphere as it was when observed by Voyager 2 (Roddier *et al.* Icarus **136**, 168).
- 3) *First ground-based detection of Neptune's arcs and dark satellites.* Deep images taken in July 1998 with our new adaptive optics system (Hokupa'a) revealed four of the dark satellites discovered by Voyager 2. In addition to Proteus previously detected before, Larissa, Galatea, and Despina were detected for the first time from a ground-based telescope, and their infrared magnitudes were estimated. Moreover, evidence was found for arcs at the distance of the Adams ring. Similar arcs were discovered by Voyager 2, but an ambiguity remained on their motion leaving two possible orbital solutions. From theoretical considerations one solution was considered to be more likely than the other. Curiously, the ground-based observation (confirmed by HST observations) was found to be consistent with the less likely solution, calling current theory into question (Sicardy *et al.*, Nature **400**, 731). Ground-based observations also showed evidence for arcs in the Leverrier ring (IAU circular **7108**), a possible transient phenomenon since no such arcs were seen by Voyager 2.
- 4) *Adaptive optics observations of active volcanoes on Io.* Observations were performed at 2.2 μm while Io was in the shadow of Jupiter. The images show the thermal emission from the active volcanoes. We observed mostly the Jupiter facing hemisphere of Io. This type observation nicely complements those made by the NIMS spectro-camera on board of

Galileo which better sees the opposite hemisphere of Io, but can hardly observe as well the Jupiter-facing side. More than half a dozen heat spots have been detected. Most have been identified with known surface features (Roddier *et al.*, ESO/OSA Sonthofen meeting).

- 5) *Adaptive optics observations of Titan*. We have systematically observed Titan every year since December 1994. Images of the leading hemisphere taken outside of the methane absorption bands clearly show a continental size feature rotating with Titan's surface. This series of images also contains a lot of information about the haze distribution in Titan's atmosphere, and will be analyzed for long term changes.
- 6) *Independent infrared photometry of Pluto and Charon*. Results showed differences in surface composition and surface heterogeneities. Evidence was found for an excess of ice on Charon (Tholen *et al.*, Icarus, submitted).
- 7) *Surface mapping of Ceres, Pallas and Vesta*. Ceres and Pallas were observed through narrow band filters centered in and out of the absorption bands of water ice to search for local concentration of ice on their surface. Vesta was observed through narrow band filters that match the absorption band of pyroxene, feldspar and olivine to map the composition of its highly cratered surface.
- 8) *Search for binary asteroids*. Most recently, we made a systematic search for binary asteroids with the CFHT user adaptive optics system (Pue'ou). This search led to the discovery of a companion to (45) Eugenia (Merline *et al.* Nature **401**, 565). This is only the second asteroid known to have a companion, and the first one discovered from the ground.

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